Transformer Life Extension

CJC V30 Transformer Oil Vacuum Filtration Unit and Ion Exchange Filtration Units
Agenda

- Examples of V30 installations
- Background info
- Theory
- Field results
- Added safety
- Conclusion
V30 – Kläppa, Ljusdal Sweden.
The V30 Vacuum Filter
Installed at Rathkeale Power Station, Ireland
V30 – Mo I Rana, Norway
Examples of other V30 installations.
V30 Production
C.C.Jensen A/S, Svendborg
Why is a CJC Vacuum Filter needed?

- The CJC Vacuum Filter (CJC V30) is designed to continuously filter power transformer insulating oil, thereby extending the transformer’s life, and postponing investment in a new transformer.

- The average age of the power transformers in Europe is increasing every year and with the age the number of failures. The V30 will minimise the risk of ageing related transformer failure.

- Estimates from insurance companies show that the number of transformer failures will peak in 2013-2015, so now is the time to act!
This is what we want to prevent
How does a CJC V30 extend transformer life?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>By removing <strong>oxygen</strong> from the transformer oil. Down to 200 ppm.</td>
</tr>
<tr>
<td>2</td>
<td>By removing <strong>water</strong> from the transformer oil. Down to 4ppm.</td>
</tr>
<tr>
<td>3</td>
<td>By filtering <strong>particles</strong> and sludge from the oil.</td>
</tr>
<tr>
<td>4</td>
<td>By reducing the <strong>acid</strong> number (TAN). With a combined V30 and HDU ion exchange</td>
</tr>
<tr>
<td></td>
<td>filter <strong>acid</strong> is removed – down to 0.01 mg KOH/g</td>
</tr>
</tbody>
</table>
## Results using a V30/Ion Exchange Filter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Typical value for aged system</th>
<th>After filtration</th>
<th>Time frame</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water in oil</strong></td>
<td>20-40 ppm</td>
<td>4 ppm</td>
<td>years</td>
</tr>
<tr>
<td><strong>Water in cellulose</strong></td>
<td>2-7%</td>
<td>0.6-1.1%</td>
<td>years</td>
</tr>
<tr>
<td><strong>Particles, ISO</strong></td>
<td>14/10-16/13</td>
<td>11/8</td>
<td>days</td>
</tr>
<tr>
<td><strong>Breakdown Voltage/2.5mm</strong></td>
<td>35-60 kV</td>
<td>&gt;75 kV</td>
<td>days</td>
</tr>
<tr>
<td><strong>Bubble Formation Temp</strong></td>
<td>95°C</td>
<td>170°C</td>
<td>weeks</td>
</tr>
<tr>
<td><strong>Oxygen</strong></td>
<td>20000-25000 ppm</td>
<td>200-2000 ppm</td>
<td>weeks</td>
</tr>
<tr>
<td><strong>Tan delta@ 90°C</strong></td>
<td>0.0500-0.1500</td>
<td>0.0050</td>
<td>months</td>
</tr>
<tr>
<td><strong>Acid</strong></td>
<td>0.10-0.25 mg KOH/g</td>
<td>0.01-0.02 mg KOH/g</td>
<td>months</td>
</tr>
</tbody>
</table>
V30 Specifications

Oil flow: 270 L/h (6.5 M3/day)
Suitable for transformers: from 2.000 L up to >100.000 L
Supply voltage: 3x230-400/440V or 1x230V
Supply frequency: 50/60 Hz
Weight: 150 kg
Degassing Vacuum Pressure: 2 mbar
V30 Vacuum Filter - Principle of Operation
Transformer Ageing Overview

• The life time of a transformer depends on the life time of the cellulose insulation. The life time of the cellulose depends on the condition of the oil. When the cellulose no longer has the mechanical strength to withstand a short circuit the transformer is likely to fail.

• The cellulose is not easily accessible. Thus the oil is used as the media of transportation during filtration/regeneration of a transformer.

• If the oil is kept free from oxygen, water, particles and acid a longer life time of the cellulose is obtained. In turn the entire transformer is secured.
Transformer Ageing factors

Ageing Initiators:
- Oxygen
- Water
- Acid
- Particles
- Copper ions
- Nickel ions

Ageing Accelerators:
- Temperature (Heat)
- Vibrations / Overload
- Lightning / voltage waves
- Lack of antioxidants
Cellulosic Ageing Processes

- **Oxidation**
  (depolymerisation of cellulose with oxygen as a reactant)

- **Acid-hydrolysis**
  (depolymerisation of cellulose using H+ ions in water as reactant)

- **Pyrolysis**
  (depolymerisation of cellulose at elevated temperatures)
Transformer Ageing Circle
[source: Lars Lundgaard, SINTEF]

Hypothesis:

Oxygen ($O_2$) reacts with oil to form acids by oxidation. These acids react with water ($H_2O$) to form water and acids, which accelerate paper ageing. Paper ageing exacerbates the formation of water and acids. This leads to oil reclaiming and transformer refurbishment to break the cycle.
Condition Monitoring
Significance of the key parameters

- **Gas concentration/development**: Tells us the actual condition and performance of the transformer. Faults such as corona, arcing, hot spots, partial discharges. (IEC 60599)
- **Acid Number (TAN)**: Acidic compounds in the transformer oil. Yields information on the deterioration level (acidic byproducts) of the oil and cellulose. (IEC 60296)
- **Water content**: Tells us how critical the condition of the cellulose is. High water content results in lower breakdown voltage which in turn can cause partial discharges. (IEC 60814)
- **Particle Content**: Particles can cause accelerated wear and reduction in breakdown voltage (ISO 4406)
- **Anti-oxidants**: Inhibitor that prevents oxidation. The residue tells us how deteriorated the oil is. Produces water. BHT (or DBPC) (IEC 60666)
- **Temperature**: Tells us something about the actual load. Figures should be compared with a gas analysis. High temperature + presence of acetylene is an indication of a faulty transformer.
- **Breakdown Voltage**: Tells us something about oil electrically conduction contamination (particles, sludge, water). Particles may be wet cellulose fibers. Low dielectric breakdown voltage indicates the presence of electrically conductive contaminants in oil. (IEC 60156)
- **Tangens delta (power factor)**: Gives information on dielectric losses. Important to new oil quality as well as regenerated oil. The dissipation factor is a measure of the power lost when an electrical insulating liquid is subjected to an ac field. The power is dissipated as heat within the fluid. A low-value dissipation factor means that the fluid will cause little of the applied power to be lost. The test is used as a check on the deterioration and contamination of insulating oil because of its sensitivity to ionic contaminants. (IEC 60247)
- **Surface Tension (IFT)**: Gives information on the level of impurities in the oil. Interfacial tension and acid number (sometimes called neutralization number or acidity) are affected by oxidation and contamination. IFT is an excellent means of detecting oil-soluble polar contaminants and oxidation products in insulating oils. (ISO 6295)
- **Furfuraldehyde (Furans)**: Oil soluble oxidation products from degradation of cellulosic insulation. Can be used to estimate the DP-value (IEC 61198)
- **Color/Appearance**: General indicator of the condition of the oil. (ISO 2049)
- **Degree of Polymerisation**: Mechanical strength of cellulose.
- **Other parameters**: Flaming point, Density, Viscosity, Pour Point, Resistivity, Sulfur Content, Copper Content, Crystallisation Point, Aniline Point etc.
# Oil Condition Assessment Tests and Limits

<table>
<thead>
<tr>
<th>Test Item</th>
<th>Method</th>
<th>Unit</th>
<th>Limit Value</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dielectric Breakdown Voltage (minimum)</td>
<td>ASTM D 1816</td>
<td>kV</td>
<td>Voltage: &lt;= 69kV 69-288kV &gt;345kV</td>
<td>[C57.106]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>.04” gap: 23 26 26</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>.08” gap: 34 45 45</td>
<td></td>
</tr>
<tr>
<td>Interfacial Tension (IFT, minimum)</td>
<td>ASTM D 971</td>
<td>mN/m</td>
<td>Voltage: &lt;= 69kV 69-288kV &gt;345kV</td>
<td>[C57.106]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>24 26 30</td>
<td></td>
</tr>
<tr>
<td>Acid Number (KOH, maximum)</td>
<td>ASTM D 974</td>
<td>mg/KOH/g</td>
<td>Voltage: &lt;= 69kV 69-288kV &gt;345kV</td>
<td>[C57.106]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.2 0.2 0.1</td>
<td></td>
</tr>
<tr>
<td>Water (H₂O, maximum)</td>
<td>ASTM D 1553</td>
<td>ppm</td>
<td>Voltage: &lt;= 69kV 69-288kV &gt;345kV</td>
<td>[C57.106]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>35 25 20</td>
<td></td>
</tr>
<tr>
<td>Power Factor (PF, maximum)</td>
<td>ASTM D 924</td>
<td>%</td>
<td>Voltage: &lt;= 69kV 69-230kV &gt;345kV</td>
<td>[C57.106]</td>
</tr>
<tr>
<td></td>
<td>PFVO/SFL</td>
<td></td>
<td>@25°C 0.15 0.1 0.05</td>
<td>[Gri87]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>@100°C 1.5 1.0 0.3</td>
<td></td>
</tr>
<tr>
<td>Oxidation Stability (SFL, minimum)</td>
<td>ASTM D 2440</td>
<td>Hours</td>
<td></td>
<td>[C57.106]</td>
</tr>
<tr>
<td></td>
<td>PFVO/SFL</td>
<td></td>
<td></td>
<td>[Gri87]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>80f</td>
<td></td>
</tr>
<tr>
<td>Electrostatic Charging Tendency (ECT, minimum)</td>
<td>-</td>
<td>μC/m³</td>
<td></td>
<td>[Gri90]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-500g</td>
<td>[Hey98]</td>
</tr>
</tbody>
</table>
Strength of the Insulation Cellulose

The cellulose loses its mechanical strength when a degree of polymerisation of 200 is reached.

[sources: shown by various researchers]

As the cellulose is aged (degraded) carbon monoxide and carbon dioxide are formed as well as acid and water which in turn accelerate the ageing process.
Causes of transformer failure

- 70% of all failures happen on transformers older than 30 years
- 50% of the failures originate in OLTC (Tap Changers) and lead-in bushings
- 15-20% are due to reduced stability; water and particles in the insulation
- 3-5% due to far progressed ageing
- 10-15% due to core mechanically weakened by twisting
- Old constructions may have gas problems due to induction loss

[source: Doble]

<table>
<thead>
<tr>
<th>Cause of Failure</th>
<th>Number</th>
<th>Total Paid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulation Failure</td>
<td>24</td>
<td>$149,967,277</td>
</tr>
<tr>
<td>Design /Material/Workmanship</td>
<td>22</td>
<td>$64,696,051</td>
</tr>
<tr>
<td>Unknown</td>
<td>15</td>
<td>$29,776,245</td>
</tr>
<tr>
<td>Oil Contamination</td>
<td>4</td>
<td>$11,836,367</td>
</tr>
<tr>
<td>Overloading</td>
<td>5</td>
<td>$8,568,768</td>
</tr>
<tr>
<td>Fire /Explosion</td>
<td>3</td>
<td>$8,045,771</td>
</tr>
<tr>
<td>Line Surge</td>
<td>4</td>
<td>$4,959,691</td>
</tr>
<tr>
<td>Improper Maint/Operation</td>
<td>5</td>
<td>$3,518,783</td>
</tr>
<tr>
<td>Flood</td>
<td>2</td>
<td>$2,240,198</td>
</tr>
<tr>
<td>Loose Connection</td>
<td>6</td>
<td>$2,186,725</td>
</tr>
<tr>
<td>Lightning</td>
<td>3</td>
<td>$657,935</td>
</tr>
<tr>
<td>Moisture</td>
<td>1</td>
<td>$175,000</td>
</tr>
<tr>
<td></td>
<td>94</td>
<td>$286,628,811</td>
</tr>
</tbody>
</table>

Table –3 Cause of Failures
Cost of Transformer Failures in %
[source: HSB part of PD power transf. USA, Asia, Europe and South America, 1998-2000]
Diagnostic methods

- Oil sampling, general oil analysis
- Gas analysis (DGA, IEC 60599, Roger’s Ratio, Duval’s Triangle, CEGB codes, fuzzy logic software)
- On-line gas monitoring, type Hydran 201, Kelman PGA07 etc.
- Water/Temperature measurement
- Paper samples
- Furan analyses, 2FAL (indirect DP measurement)
- IDA 200 (frequency response measurement)
- Partial Discharge (PD) measurement (electrical and acoustic)
- Vibration measurement (motor driven switch gear)
Gases generated during a fault

Combustible Gas Generation vs. Approximate Oil Decomposition Temperature

Partial Discharge (Not Temperature Dependent)

Range of Normal Operation

Hydrogen ($H_2$)

Methane ($CH_4$)

Ethane ($C_2H_6$)

Ethylene ($C_2H_4$)

Acetylene ($C_2H_2$)

200°C

300°C

Gas Generation (Not to Scale)

Approximate Oil Decomposition Temperature above 150°C
Ageing of Cellulose

Accelerated ageing of cellulose for various setup parameters.

**Influence from transformer treatment**

**Ageing under 110°C and 2.5% water in paper**

![Graph showing ageing time hours vs. age with various conditions and treatments.](image-url)
Ageing of Cellulose – no oxygen present

Fig. 6  Effect of water on the rate of aging under nitrogen at 120°C

- d AW + 1% water
- e AW + 2% water
- f AW + 4% water
- g AW (dry)
Acid generation accelerates when water and oxygen are present. Acid in turn causes acid-hydrolysis.
## Bubble Formation

<table>
<thead>
<tr>
<th></th>
<th>Gas</th>
<th>Water</th>
<th>Bubble Temp after a few weeks</th>
<th>Bubble Temp after a few years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before degassing</td>
<td>10%</td>
<td>5%</td>
<td>95 °C</td>
<td>n.a.</td>
</tr>
<tr>
<td>After degassing</td>
<td>0.5%</td>
<td>1%</td>
<td>110 °C</td>
<td>170 °C</td>
</tr>
</tbody>
</table>

\[
T = \left[ \frac{6996.7}{22.454 + 1.4495 \ln W - \ln P} \right] - \left[ \exp \left( 0.473W \times \frac{g}{30} \right)^{1.585} \right] \quad (\text{Eq. 5})
\]
Lowering the Oxygen Concentration Slows Down Oxidation

Depolymerisation of Cellulose. Accelerated Ageing (130 C)
With/Without Presence of Oxygen
Results on ageing cellulose under selective conditions.

![Graph showing electric strength versus temperature of cellulose paper impregnated under different conditions.](image)

**Figure 6**: Electric strength versus temperature of cellulose paper impregnated under different conditions.

<table>
<thead>
<tr>
<th>Condition</th>
<th>20°C</th>
<th>60°C</th>
<th>100°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dried, impregnat. aged</td>
<td>-1.32%</td>
<td>-1.76%</td>
<td>-4.0%</td>
</tr>
<tr>
<td>Impregnated - aged</td>
<td>-6.68%</td>
<td>-7.64%</td>
<td>-4.8%</td>
</tr>
</tbody>
</table>

**Table 7**: Electric strength rate versus temperature oil impregnated papers after different aging processes relatively to the unaged sample.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Tan δ (x10⁻⁴)</th>
</tr>
</thead>
<tbody>
<tr>
<td>unaged samples</td>
<td>26.75</td>
</tr>
<tr>
<td>samples aged under vacuum</td>
<td>25</td>
</tr>
<tr>
<td>samples aged at atmospheric air</td>
<td>53.57</td>
</tr>
</tbody>
</table>
Oxygen

No Oxidation without Oxygen
Effects of Oxygen

Initiation,
Metal ions + oxygen -> MeOO.
Cell-H + MeOO. -> Cell. + MeOOH

Propagation,
Cell. + O2 -> Cell-OO.
Cell-OO. + Cell-H ->Cell-OOH+Cell.

Oxygen or Water can not chemically react with the cellulose material.
However, oxygen together with for example metal ions (Copper) form unstable very reacting radical species, which decompose the Kraft transformer paper creating a lot of various chemicals like CO2, water, furfural.

Water is the transport media of the reactive species.
Water also decomposes the crystalline structure in the cellulose; more amorphous cellulose will be formed. The amorphous cellulose is easier to penetrate for the unwanted radical species compared to the crystalline parts. Heat and water soften the hemicellulose and the amorphous cellulose resulting in lower paper strength.
The oxygen-free transformer

DEOX - ASEA 1977

In the years 1976 & 1977 ASEA published articles about the oxygen-free transformer. It was tested on a transformer with rubber membrane and continuous degassed including filtration.

Specification:
* oxygen : < 300 µl/l
* water : < 0,5 %
* particles : < 5 µm
* gas-free oil : 200 N/m², <1 Torr (1.33 mBar)

Conclusions:
• higher dielectric strength of the oil
• reduced ageing
• continuous monitoring of the gassing rate

These features are achieved with a new apparatus which incorporates:
1. Continuous filtration (freedom from fibers and metal particles in the oil)
2. Continuous degassing (freedom from water and oxygen, gas-hungry oil)
3. Continuous monitoring of the gassing rate for total and combustible gases.

Ageing rate reduced by a factor of 5.

[source: TG diagnostikk & Lampe et al]
V30 RESULTS

- The CJC V30 extends remaining transformer life.
- The indications for extended transformer life using a CJC V30 are very strong.
- It will however take many years to prove conclusively.
Oxygen Removal V30, Stubbekøbing

O2 Concentration vs time.
Stubbekøbing, Denmark. 8000L oil in transformer.

Oxygen concentration in oil [ppm]

0 2000 4000 6000 8000 10000 12000 14000 16000 18000 20000 22000


Time

V30 Started
V30 Stopped

0 720 580 200 1940 5870 1307
Oxygen content & Carbon Monoxide Generation i.e. Rate of paper degradation

Koncentration O2 [ppm]

Tid


V30 Started

O2/CO2

O2 Concentration IND
Degassing a 20000 L power transformer.
Hydran 201i readings TR2, Sondrio
Hydran reading [ppm] = 100% H2 + 18% CO

- Temporary degassing unit.
- V30 vacuum filter. Permanent degassing unit. Oil flow 3L/min.
- V30 started. Oil flow not adjusted correctly (<1L/min).
- Equilibrium has not yet been reached. It will be reached sometime in the near future.
CO/CO2 ratio

CO/CO2 Ratio

CO/CO2 Ratio
Water

- Moisture, especially in the presence of oxygen, is extremely hazardous to transformer insulation.

  [quote: FIST – Transformer Maintenance]

- Moisture reduces the insulating ability of the cellulose. Number of partial discharges increases.
- Water acts as the transportation media for acid and ions
- High moisture content >> higher risk of free water in oil
- High moisture content >> larger amount of pulsating water during daily temperature variations.
- Aged oil can contain more water. This is due to a higher level of polar compounds.
Water

Water uptake from the atmosphere

\[ W_{rel}(t, RH) = (a \cdot RH + b) \left( 1 - e^{-\frac{t}{k}} \right) \]
Water in oil – Water in cellulose relation

\[ \log(\text{Water ppm}) = A - \frac{B}{T} \]

Where \( A = 7.09 - 7.42 \); \( B = 1567 - 1670 \)

<table>
<thead>
<tr>
<th>T (°C)</th>
<th>Oommen</th>
<th>Griffin</th>
<th>Shell</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>20</td>
<td>23</td>
<td>22</td>
</tr>
<tr>
<td>10</td>
<td>33</td>
<td>36</td>
<td>35</td>
</tr>
<tr>
<td>20</td>
<td>53</td>
<td>56</td>
<td>55</td>
</tr>
<tr>
<td>30</td>
<td>82</td>
<td>83</td>
<td>84</td>
</tr>
<tr>
<td>40</td>
<td>122</td>
<td>122</td>
<td>124</td>
</tr>
<tr>
<td>50</td>
<td>179</td>
<td>174</td>
<td>180</td>
</tr>
<tr>
<td>60</td>
<td>255</td>
<td>243</td>
<td>255</td>
</tr>
<tr>
<td>70</td>
<td>358</td>
<td>334</td>
<td>355</td>
</tr>
<tr>
<td>80</td>
<td>491</td>
<td>450</td>
<td>484</td>
</tr>
<tr>
<td>90</td>
<td>663</td>
<td>596</td>
<td>648</td>
</tr>
<tr>
<td>100</td>
<td>880</td>
<td>777</td>
<td>855</td>
</tr>
</tbody>
</table>
V30 Water Removal. Laboratory.

Water removal efficiency is temperature independent.
V30 efficiency of water removal
Example: 20 ppm in >> 6 ppm out
Water Removed from a transformer.

- The water which is removed with a V30 is often acidic. This water had a pH of 4.7
- As the water is drained from the cellulose the pH is lowered indicating the removal of acid from the cellulose into the oil.
Water removal on transformer Brønshøj, Denmark

Water content oil and cellulose (calculated) with a CJC V30 vacuum filter installed on BRT1(8000L).

Water content in the oil [ppm], Temperature [°C]

- Water in oil
- Water in cellulose

CJC V30 Vacuum Filter
Started 22-01-2001
Water removal on a transformer, Stubbekøbing
Water removal. Kläppa Ljusdal, Sweden. 59300 L

Water content in the oil. V30 installed on a 59300L transformer - Ljusdal, Sweden. Temperature variations between 40 and 50 C.

Water content in oil [ppm]

V30 Started

Water [ppm]
Water Removal on a power transformer

Water content in oil [ppm] and oil temperature [°C]. 20000 L transformer.

Oil Temperature [°C] - Water concentration [ppm]

- Oil temperature [°C]
- ppm calculated
- T [°C] from sensor
- Water Content [ppm] (sensor)
- 30 per. Mov. Avg. (Oil temperature [°C])
- 30 per. Mov. Avg. (ppm calculated)
Water Content of oil during drying with a V30

Water removal on T3, Filaret, Bucarest, Romania. 20000L oil. 40MVA.
Water Content in oil at T=36 C.

The water content of the oil is highly temperature dependent due to the equilibrium with the transformer cellulose. The graph shows the water content at 36 C. As can easily be seen from the curve the V30 has been lowering the water content in the oil to roughly 7-8 ppm.
Removed water on a 20000L transformer

Accumulated amount of water removed from the transformer insulation

[ Liters ]

<table>
<thead>
<tr>
<th>Time</th>
<th>Removed Water (accumulated) [L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004-02-23</td>
<td>0.0</td>
</tr>
<tr>
<td>2004-03-04</td>
<td>0.5</td>
</tr>
<tr>
<td>2004-03-14</td>
<td>1.0</td>
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<tr>
<td>2004-03-24</td>
<td>1.5</td>
</tr>
<tr>
<td>2004-04-03</td>
<td>2.0</td>
</tr>
<tr>
<td>2004-04-13</td>
<td>2.5</td>
</tr>
<tr>
<td>2004-04-23</td>
<td>3.0</td>
</tr>
<tr>
<td>2004-05-03</td>
<td>3.5</td>
</tr>
<tr>
<td>2004-05-13</td>
<td>4.0</td>
</tr>
</tbody>
</table>
Water Removal = Life Extension

• Starting with 62 L of water in the insulation
• The V30 has removed 4.3% of that water (2.7 L) during the first 9 weeks.
• That’s an average of 37 mL/day
• Cutting water content in half (by removing 31L) will double the cellulose life.
• Assuming a remaining life time of 15 years, removing 2.6L will add 1.2 years of life to the transformer cellulose.
• Removing 31 L will take approximately 2 years and 3 months.
Acid

Acids cause an increase in the rate of decay, which forms more acid, sludge, and moisture at a faster rate. This is a vicious cycle of increasing speed forming more acid and causing more decay.

To prevent the oil from being oxidized antioxidants are added. Anti-oxidants react with radicals.

If the acid number TAN starts to increase dramatically it is indicating that the reserves of anti-oxidants are used up.

Important: If TAN once has increased to an unacceptable level the cellulose may be damaged.

Formerly TAN<0.20 mg KOH / g was acceptable

Now this value is 0.10 mg KOH / g for smaller transformers.

When TAN exceeds 0.40 mg KOH / g the oil starts to form sludge which deposits on the windings.

A CJC ion exchange insert transformer oil filtration treatment can reach a TAN value of 0.01.
CJC Acid Reduction Systems

Syratal mg/KOH/g olja

Start med nya EO-insats

Byte av EO-insats

Byte av EO-insats

Byte av EO-insats

Byte av EL-insats

Byte av EL-insats

Byte av EL-insats

Tid i månader

Okt Nov Dec Jan Feb Mar Apr Maj Jun Jul Aug Sep Okt Nov

ADSORPTION BY FULLER'S EARTH

INITIAL NEUTRALIZATION NUMBER OF OIL TO BE TREATED [KOH NUGG'S OF OIL]
Acid Reduction - Sira Kvina Transformer Norway.

TAN - Sira Kvina Transformer: 22500 kg. Hydro Power Transformer. CJC ion exchange filtration. Starting TAN=0.11 mg KOH/g.

![Graph showing the decrease in Total Acid Number (TAN) from 0.11 mg KOH/g to below 0.01 mg KOH/g over time. The graph includes a note that "CJC HDU 3 * 27/108 ion exchange filter started" on the x-axis at 15-12-2003.]
Particles

- Even small amounts of particles in the transformer lower the dielectric strength of the transformer oil.
- The CJC V30 filter insert removes particles down to 0.4 micron.
- Removing Cu, Pb, Fe & Zn, cellulose fibers and carbon usually found in transformers increases dielectric strength.

[Source: Effect of particles on Transformer Dielectric Strength. Cigré WG 17]
V30 Vacuum Filter - Early Warning Systems

The CJC V30 Vacuum Filtration Unit equipped with standard as well as optional sensors will operate as an early warning system for the transformer. This includes:

1) Gassing alarm on V30 – indication of a high thermal fault in the transformer
2) Increased water in oil detection – indication of a low thermal fault
3) Specific gasses produced – high thermal fault – more sensitive than gassing level. Direct online gas measurement. Hydrogen, Methane, Carbon Monoxide.
4) Abnormal rise in oil temperature – detects large scale heating
5) ComPosIT GSM datalogger. Alarm via sms. Data on WWW

Especially the gas sensor will yield important information – and a very early warning for a possible fault.
Conclusion

• By lowering the Oxygen concentration in the oil, the oxidation (degradation) of the cellulose is reduced
• By removing water from the transformer the remaining life time is increased
• By removing particles the break down voltage is increased
• By reducing acidity levels the transformer cellulose is better protected against ageing acceleration